

PATENT SPECIFICATION

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PROVISIONAL SPECIFICATION

Improvements in or relating to Methods and Apparatus for Reducing the Effect of Interference in the Observation of Recurrent Oscillatory Signals

We, ALAN DOWER BLUMLEIN, of 37, The Ridings, Ealing, London, W.5, and ERIC LAWRENCE CASLING WHITE, of 7, Vine Lane, Hillingdon, Middlesex, both 5 British subjects, do hereby declare the nature of this invention to be as follows:—

This invention relates to improvements in methods and apparatus for reducing the 10 effect of interference in the reception of signals, more particularly in the case of signals which consist of waveforms which are regularly repetitive.

In the reception of such signals, interference may be caused by unwanted interference signals from some source external to the receiver, or if the signals to be received are very weak, by the thermal agitation or valve noise generated in the 20 receiver itself. It is known that such interference may be reduced by limiting the effective band width of the receiver to the minimum required to pass the waveform of the signal to be received. For example, receivers for modulated carrier 25 wave signals are usually designed so that the bandwidth of their pre-detector circuits is limited to twice the maximum modulation frequency and their post 30 detector stages are designed only to pass frequencies up to the highest modulation frequency.

If, however, the signal to be received is of such a character that its sidebands 35 do not continually occupy the whole of the bandwidth provided in the receiver, it is possible further to reduce the effects of interference by modifying the selectivity of the receiver in such a manner 40 that those portions of the pass band in which side bands or modulation frequencies are continually absent are eliminated, with the result that those components of interference which are present 45 in such bands do not appear in the output of the receiver.

It is the object of this invention to provide an improved method of reception in

which the effects of interference upon a repetitive waveform are reduced by effectively limiting the pass band of the receiver to those frequency bands containing components of the repetitive signals which are to be received.

According to one feature of the present 55 invention a method for the reception of a signal having a regularly repetitive waveform comprises feeding said signals to a channel which is only permitted to pass signals for time intervals at approximately the repetition frequency of the waveform of said signal, and then integrating the signals passed by said channel in a number of successive time intervals, whereby the amplitude of the 60 signal to be received is increased in relation to the amplitude of random interference occurring in the successive time intervals. The length of the said time interval is preferably shorter than or comparable with the period of the highest frequency which it is desired to observe in the repetitive waveform of said signal.

The repetitive waveform may be a modulated carrier wave, in which case the 75 integration may be applied in a carrier frequency stage of the receiver prior to detection or in a post detector stage of the receiver or in both.

According to a further feature of this 80 invention said time intervals are successively displaced in phase whereby the signal passed by said channel in successive time intervals is representative of successive portions of said repetitive waveform 85 so that the variation of the signal passed by said channel during a number of successive time intervals may be made to reproduce the whole or part of said repetitive waveform.

According to another feature of this 90 invention, apparatus for carrying out the improved methods of reception hereinbefore referred to preferably comprises a receiver having an input circuit with a 95 relatively wide pass band to which the

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- signals to be received are arranged to be fed, a channel comprising one or more valves adapted to be blocked so as to have their transmission reduced to zero except at predetermined time intervals, and integrating means comprising an oscillatory circuit with a relatively narrow pass band. The receiver may conveniently be a superheterodyne radio receiver having a low intermediate frequency amplifier of high selectivity, in which case the heterodyne oscillation should preferably be correlated with the carrier frequency of the transmitter so as to permit said oscillation to follow small variations in the frequency of said carrier signal.

One example of the invention will now be described.

A method for the determination of the direction and position of aircraft has been described in co-pending Application No. 21108/39 (Serial No. 581,920) according to which short bursts of radio frequency oscillations are successively transmitted at predetermined intervals and are reflected back to a system of receivers by aircraft or other reflecting objects. When such aircraft are a considerable distance away from the transmitter and the receiving apparatus, the reflected signal is very weak and may be below the noise level of the receiver. The signal has, however, a regularly repetitive waveform, and the effects of noise or interference upon its reception may be reduced by the application of the invention in the manner which will now be described. It will be assumed in the following description that the transmitter radiates an unmodulated carrier at a frequency of 100 megacycles per second for 0.5 microseconds intervals, there being 5,000 intervals per second.

The signals reflected from the aircraft are picked up by an aerial and fed to a receiver. The initial stages of the receiver are designed to accept the frequency band 100 ± 1.5 megacycles per second in order to permit them to follow an envelope waveform having a time of rise of 0.8 microseconds. One or more of these initial stages of the receiver are arranged to be normally quiescent, i.e. not to pass signals. This may be accomplished by including thermionic valve amplifying stages which are normally biassed beyond current cut-off in well known manner. Voltage pulses are, however, applied to these stages so as to make them operative to pass signals only for short time intervals of approximately 0.5 microseconds every $\frac{1}{500}$ sec. when the reflected signals to be received are present. Such pulses may be derived in known manner from a multivibrator pulse generator which is controlled by a master pulse generator through an adjust-

able phasing device and may be applied in the positive sense to one or more of the control electrodes of said stages in known manner, so as to bring the valves on to the operating parts of their characteristics. 70

The signals emerging from the "pulsed" stages which have just been referred to are next heterodyned down to a frequency of the order of 20 kilocycles per second. This may be accomplished in successive stages; for example, the signals may first be heterodyned to a frequency of 10 megacycles per second, then to 300 kilocycles per second and finally to 20 kilocycles per second by mixing with local oscillations of appropriate frequency. The 10 megacycles per second stages may have a bandwidth of ± 200 kilocycles per second, the 300 kilocycles stages a bandwidth of ± 3 kilocycles per second and the final 20 kilocycles per second stages a bandwidth of ± 200 cycles per second. In order to reduce the effect of oscillator drift, the local oscillations may be derived in known manner by mixing an oscillation derived from the carrier frequency oscillator of the transmitter with an oscillation of the desired intermediate frequency derived from an oscillator, the frequency stability of which is good relative to the pass band required of the desired intermediate frequency. For example, the first heterodyning oscillation may be obtained by mixing the carrier frequency oscillations from the transmitter with a stable oscillation of 10 megacycles per second, the frequency drift of the latter oscillator being small with reference to 200 kilocycles per second. Alternatively, the carrier frequency of the transmitter may be synthesised from a number of lower frequency oscillations including those required for the heterodyning stages of the receiver. Thus, if the I.F. frequencies of the receiver are to be 10 megacycles/sec., 300 kilocycles/sec. and 20 kilocycles/sec. respectively, and the frequency of the transmitted carrier and the reflected signal to be received is 100 megacycles/sec., the local oscillator frequencies required will be 90 megacycles/sec., 9.7 megacycles/sec. and 298 kilocycles/sec., respectively. These frequencies may be generated by starting with oscillations operating at frequencies of 20 and 280 kilocycles/sec., 115 mixing these oscillations to give the 300 kilocycles/sec. oscillation; mixing this 300 kilocycle/sec. oscillation with a 9.7 megacycles/sec. oscillation to give a 10 megacycle oscillation and finally mixing 120 this 10 megacycle oscillation with a 90 megacycle oscillation to give the 100 megacycle oscillation required for the transmitter. Any variation of frequency in these oscillations which may occur will 130

then not cause any de-tuning of the final 20 kilocycle/sec. I.F. signal. This arrangement has the further advantage that, since the heterodyning oscillation is 5 not derived from a signal frequency oscillation, the risk of a slight admixture of the signal frequency in the heterodyning frequency is prevented and interference, which the presence of such a component would cause, is therefore avoided.

The effect of the successive heterodyning and bandwidth limitation process which has just been described is to integrate the successive bursts of the 15 reflected signals which are passed to the "pulsed" stages of the receiver. If the aircraft giving the reflected signals has no component of velocity towards the transmitter and receiver, then the successive 20 bursts of incoming signals will arrive in the same phase every $\frac{1}{5000}$ sec., and will each set up oscillations in the final intermediate frequency circuits of the receiver. In view of the small pass band 25 of these circuits and their correspondingly low decrement, the oscillation set up by each burst of incoming signals will persist and will be reinforced by the next burst and so on, with the result that the amplitude 30 of the oscillation set up will be proportional to the number of oscillations received. The interference which is present with the signal, however, is of a random character and the effect of the 35 interference in successive bursts of signal will not be directly additive, so that the amplitude of the signal is increased relatively to the amplitude of the interference by the process.

Although there is theoretically no limit to the number of successive signals which may be integrated, and although in theory the pass band of the final intermediate frequency may be made as narrow as possible in the particular case 45 which has been referred to above, this condition is not realised if the aeroplane has a component of velocity toward the transmitter and receiver, and the pass 50 band must therefore be widened. The aircraft may be assumed to be flying slower than 150 metres/sec. so that the maximum rate of change of path length for the radio signals to and from the aircraft is 55 300 metres/sec. This means that the path length changes by half the transmitted wavelength, i.e. 1.5 metres, in $\frac{1}{200}$ sec. so that if the addition of the bursts of reflected signals is continued for more 60 than this period, the relative phase of the radio frequency oscillator will have changed by more than 180° and the addition of further bursts of signal will reduce the resultant signal amplitude.

65 The decrement of the integrating circuit

must therefore be adjusted so that the oscillation set up by a single burst of incoming signals decays practically to zero in $\frac{1}{200}$ sec., that is, the bandwidth of the circuit must be of the order ± 100 or 70 200 cycles/sec. at 20 kilocycles/sec. Thus, 25 successive bursts of signal may be effectively added.

The operation of the system may alternatively be explained in the following 75 manner. The signal sent out by the transmitter consists of a series of bursts of high frequency carrier and a signal of this type may be regarded as a continuous high frequency oscillation modulated by 80 a recurrent waveform consisting of a short pulse followed by a long interval. Such a waveform may be analysed into a series of components having frequencies equal to the repetitive frequency of the 85 pulse and numerous harmonics of this repetitive frequency. The signal sent out by the transmitter therefore comprises a large number of component frequencies, namely, the carrier frequency and 90 numerous sidebands spaced apart at the repetitive frequency. In the particular example quoted above the spectrum of the transmitted signal would consist of the carrier at 100 megacycles/sec. and a sequence of sidebands at $100 \pm .005 n$ 95 megacycles/sec., where n may be 300 if the bandwidth of the transmitter is ± 1.5 megacycles/sec.

If the aircraft giving rise to the reflected signal is stationary, the reflected signal will be of the same waveform and will have the same component frequencies, but if it is moving, the Doppler effect will modify these frequencies, and it can be shown that for aircraft speeds up to 150 metres/sec. and a carrier frequency of 100 megacycles/sec., the shift of frequency will not exceed 100 cycles/sec. The component of the reflected signals 110 will therefore always lie well within one series of frequency bands ± 200 cycles/sec. wide centred at the frequencies $100 \pm .005 n$ megacycles/sec., and in the reception 115 of such signals only these frequency bands are required.

The frequency bands required for the reception of the reflected signal may be still further narrowed by taking up the frequency shift due to the Doppler effect 120 either manually or automatically. Thus, the frequency of the heterodyning oscillators may be varied by small variable condensers in their frequency determining circuits so as to maintain the 125 frequency of the final I.F. signal at its assigned value and thus permit the bandwidth of the final I.F. circuits to be reduced considerably below ± 200 cycles/sec., thereby effecting a further reduction 130

in the effect of interference. The necessary variation of frequency may be made manually by an observer or may be effected by the known methods of automatic frequency control.

The receiving system which has been described above does provide a system which only receives signals falling within such frequency bands. The effect 10 of "pulsing" may be regarded as mixing or heterodyning the incoming signals by means of a pulse waveform comprising the frequency of 5,000 cycles/sec. and numerous harmonics of the frequency 15 which together make up the pulse waveform. If the "pulsed" stages are followed by a heterodyning stage which effectively limits the pass band to ± 200 cycles/sec., then it is clear that only 20 input signals having frequencies lying within ± 200 cycles/sec. of the carrier frequency and a series of frequencies spaced from the carrier frequency by 25,000 cycles/sec. intervals can give rise to 25 an output in the heterodyning stage so that response of the receiver is effectively limited to those frequency bands containing some component of the signal to be received and in consequence the ratios 30 between the signal and interference is improved due to the fact that contribution to interference by frequency bands not containing frequency components of the desired signal are removed.

35 In the arrangement described above, certain stages of the receiving apparatus are "pulsed" at times when the received bursts of oscillation are present. The phase of the "pulsing" may, however, be adjusted to occur at any instant 40 within the $1/500$ sec. repetition frequency, and if the incoming signal is accurately repetitive over a large number of successive "bursts" of carrier oscillation the 45 phase of the pulse may be continuously adjusted over the $1/500$ sec. period during a much longer period of say 2 seconds.

The phase of the switching pulses may 50 be controlled in the manner required for the above methods by feeding the 5,000 cycles/sec. pulses from the master pulse generator through a phase rotating device which may be similar to a goniometer with the two fixed coils excited from the 55 master pulse generator 90° out of phase with each other. The moving coil of the goniometer will then have induced in it a series of pulses, the phase of which may be varied by rotating the moving coil in 60 relation to the fixed coils, and this series of pulses may be used to control the switching of the receiver. The moving coil of the goniometer may then be arranged to be rotated by a suitably 65 geared motor, completing a revolution in

the time period, which may be 2 seconds, during which the complete observation of the repetitive waveform is to take place. The sawtooth scanning voltage for the oscilloscope may be synchronised with 70 this device so that the forward stroke of the scanning voltage commences at the appropriate instant and the repetitive waveform will then be traced on the screen of the oscilloscope. If the signal 75 from the detector of such a receiver is fed to a pair of plates of an oscilloscope having a long lag fluorescent screen which is scanned by means of a sawtooth waveform having a period of 2 seconds, there 80 will be traced on the screen of the oscilloscope a curve representing the amplitude of successive elements of the waveform derived from successive pulsing cycles; in other words, the mean waveform over a 85 large number of successive bursts of incoming signals. In this way the waveform of the incoming signal may be traced at a slow rate which is sufficiently rapid in relation to the phase changes due 90 to the motion of the aeroplane to allow its position to be followed with a sufficient degree of accuracy. In working such a system, the pass band of the post detector amplifier feeding the plates of 95 the cathode ray tube may be further limited to an extent which will just allow the slight changes in waveform in successive "bursts" to be transmitted without distortion, thus permitting still 100 further reduction in the effects of interference. In the example given, the bandwidth required may be as little as ± 50 cycles/sec.

If it is desired to examine a portion 105 only of the repetitive waveform over a long succession of signals, the method described above may be used and the phase adjustment limited so that the receiver is only "pulsed" to receive the signal 110 in the neighbourhood of that portion of the repetitive cycle which is of interest. For example, the change of timing of the pulse may be limited to 2.0 microseconds spread over a period of $1/25$ secs. and the 115 necessary pulses may be generated by adding a 25 cycles/sec. sawtooth wave in the output obtained from the master 5,000 cycles/sec. pulse generator over an adjustable delay network and deriving a 120 pulse from the combined wave when its amplitude passes a given threshold and is rising. It is preferably arranged that sense of the modulation is such that the pulses are timed early at the beginning 125 of the sawtooth and become successively later in timing during the forward stroke of the sawtooth.

By adjustment of the delay introduced into the pulses by the delay network, any 130

desired portion of the repetitive waveform may be examined.

The interfering effect of a steady carrier frequency in the methods of reception which have been described above may be reduced by modulating the carrier frequency of the transmitter at a very low frequency. It will be seen that the frequency of the transmitter must not change by more than a small fraction of 5 200 cycles/sec. in $\frac{1}{5000}$ sec., as otherwise successive reflected signals will not add with a sufficient degree of accuracy because the received signal may be hetero- 10 dyned by an oscillation derived from the transmitter $\frac{1}{5000}$ after it was itself transmitted. A frequency variation of 10 cycles/sec. may, however, be permitted in $\frac{1}{5000}$ sec. and by modulating the fre- 15 quency of the transmitter so as to increase its frequency over a range of $\pm 2,500$ cycles/sec. In a period of $\frac{1}{5}$ sec. That is to say, the frequency of the transmitter may be increased steadily during $\frac{1}{10}$ sec. 20 and then decreased steadily during the following $\frac{1}{10}$ sec. and so on. This may be done by means of a mechanically rotated condenser in one of the frequency determining circuits of the transmitter. 25 30 For a steady interfering signal, this frequency modulation of the transmitted carrier will give freedom from interference from such a signal for $5000 - 400$ 500

$\times 100\%$, i.e. 82% of each $\frac{1}{10}$ sec. period. 35 A slower variation of frequency than that suggested above may of course be used.

Although the invention has been described above in relation to repetitive modulated carrier wave signals, it may also be applied to the reception of repetitive signals which do not comprise a carrier wave, for example, waveforms similar to the envelope waveform of the signals which have been hereinbefore referred to; namely, waveforms comprising short pulses separated by intervals which are long relative to the duration of the pulses. In the case of the latter signals, however, a storage device resonant to a carrier frequency is of course not employed, and is replaced by a simple integrating device, such as a condenser, which adds successive increments of signal.

The invention may also if desired be employed both prior to the detector and after the detector if the signals are in the form of repetitive modulated carrier waves.

Generally speaking, the application of the invention to signals not comprising a carrier wave is mainly useful in cases in which the level of signal is at least slightly above that of the interference, but by virtue of the storage effect at carrier frequency, which is possible when the invention is applied to carrier wave signals prior to detection, signals may be received even when the level of the signal is below that of the interference.

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Dated this 30th day of November, 1939.

F. W. CACKETT,
Chartered Patent Agent.

COMPLETE SPECIFICATION

Improvements in or relating to Methods and Apparatus for Reducing the Effect of Interference in the Observation of Recurrent Oscillatory Signals

We, ALAN DOWER BLUMLEIN, of 37, The Ridings, Ealing, London, W.5, and ERIC LAWRENCE CASLING WHITE, of 7, Vine Lane, Hillingdon, Middlesex, both 75 British subjects, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

80 This invention relates to improvements in methods and apparatus for reducing the effect of interference in the observation of recurrent oscillatory signals.

In the reception of such signals, interference may arise from some source external to the receiver, or, if the signals to be received are very weak, from the thermal agitation or valve noise generated

in the receiver itself. Such interference will be of a random nature and it is the object of the present invention to utilise this fact in order to reduce the effect of such undesired random signals in the observation of recurrent oscillatory signals.

Alternatively, random interference may be regarded as extending over a very wide frequency band, whereas the recurrent oscillatory signals will only have components at specific frequencies, and in another aspect, it may be said that the object of the present invention is to utilise this fact in order to reduce the effect of such undesired random signals in the observation of recurrent oscillatory signals.

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- According to one feature of the invention there is provided a method of observing desired recurrent oscillatory signals in a train of signals including undesired random signals which comprises feeding the signals in said train during spaced time intervals each coinciding with the whole or a part of one of said desired signals to an integrating device, which is such that oscillations are set up therein by said desired signals, said signals being fed to said device in such manner that the oscillations set up in said device by said desired signals in successive time intervals add substantially in phase, whereby the minimum value of the ratio of the amplitudes of said desired and undesired signals during said time intervals is increased.
- If desired, said integrated signals may be rectified and the rectified signals also integrated so as further to reduce the effect of said undesired random signal. Said oscillatory signals may also, if desired, be changed in frequency before integration.

According to a further feature of the invention, the above-mentioned features may be employed in the detection or determination of the position or distance of a reflecting object by radiating short bursts of oscillatory signals and receiving said oscillatory signals after reflection by said object. If the frequency of said received oscillatory signals is changed before integration, said change of frequency may be so controlled in accordance with the changes of frequency due to relative motion between said reflecting object and the receiver receiving said oscillatory signals that changes in the frequency of the oscillations of different frequency due to said motion are reduced or eliminated. The frequency of said radiated oscillatory signals may be slowly varied over a predetermined range in order to reduce the effect of interference of steady frequency.

According to another feature of the invention there is provided apparatus for carrying out the above-mentioned features, said apparatus comprising an integrating device and switching means adapted to feed said signals or parts thereof to said integrating device during said spaced time intervals, said integrating device being an oscillatory circuit of low decrement adapted to be set into oscillation by said desired oscillatory signals. Said switching means may comprise a thermionic valve which normally does not transmit signals but which is arranged to be rendered conducting so as to transmit signals during said time intervals by means of a voltage pulse applied to one of the electrodes thereof,

Said apparatus preferably comprises means for heterodyning said desired oscillatory signals to a low intermediate frequency in which case said integrating device may be an oscillatory circuit tuned to said intermediate frequency, and said apparatus may also include a further integrating device and further switching means for feeding said rectified signals to said further integrating device during spaced time intervals. Means may also be provided for controlling said intermediate frequency in accordance with variations in the frequency of said received oscillatory signals due to relative motion between said reflecting object and the radiator of said oscillatory signals. Said integrating device may be arranged to be substantially non-responsive to intermediate frequency signals resulting from the heterodyning of said oscillatory signals received after reflection by other reflecting objects moving relative to said reflecting object.

According to a further feature of the invention there is provided apparatus for detecting or determining the position or distance of a reflecting object comprising a transmitter adapted to radiate oscillatory signals at spaced time intervals and apparatus incorporating the above-mentioned apparatus features for receiving said oscillatory signals after reflection by said object, in which means are provided for deriving the heterodyning oscillations for said receiver and also said radiated oscillatory signals from a common oscillator or oscillators in such manner that changes in the frequency of the intermediate frequency signal in said receiver due to drift of the frequency of said radiated signals and/or said heterodyning oscillations is reduced. If desired, the frequency of said radiated signals and said heterodyning oscillations may be slowly varied within a predetermined frequency range.

The application of the invention to the detection of or the determination of the position or distance of a reflecting object will now be described by way of example with reference to the accompanying drawing, which shows a general schematic circuit arrangement of the transmitting and receiving apparatus.

A method for the determination of the direction and position of aircraft has been described in co-pending Application No. 21108/39 (Serial No. 581,920), according to which short bursts of radio frequency oscillations are successively transmitted at predetermined intervals and are reflected back to a system of receivers by aircraft or other reflecting objects. When such aircraft are a considerable distance away from the transmitter and the receiving

apparatus, the reflected signals are very weak and may be below the noise level of the receiver. The reflected signals are, however, regularly recurrent, and the effects of noise or interference upon their reception may be reduced by the application of the invention in the manner which will now be described. It will be assumed in the following description that the transmitter 1 radiates, under the control of the master pulse generator 6 an unmodulated carrier at a frequency of 100 megacycles per second for periods of 0.5 microseconds duration, there being 5000 such periods per second.

The signals reflected from the aircraft are picked up by an aerial 2 and fed to a receiver 3. The initial stages 4 of the receiver 3 are designed to accept the frequency band 100 ± 1.5 megacycles per second in order to permit them to follow an envelope waveform having a time of rise of 0.3 microseconds. One or more of these initial stages 4a of the receiver are arranged to be normally quiescent, i.e., not to pass signals. This may be accomplished by including thermionic valve amplifying stages which are normally biased beyond current cut-off in well known manner and to which voltage pulses are applied so as to make them operative to pass signals only for short time intervals of approximately 0.5 microseconds every $\frac{1}{500}$ sec., when the reflected signals to be received are present. Such stages may be of the kind described in the Specification of co-pending Application No. 29285/39 and the valves employed may be supplied with electrode voltages greatly in excess of the electrode voltages normally used with such valves due to the fact that only intermittent operation is required, so that the valves operate with an increased mutual conductance. Said pulses may be derived in known manner from a multi-vibrator pulse generator 5 which is controlled by the master pulse generator 6 through an adjustable phasing device 7 and may be applied in the positive sense to one or more of the control electrodes of said stages in known manner, so as to bring the valves on to the operating parts of their characteristics.

The signals emerging from the "pulsed" stages which have just been referred to are next heterodyned down to a frequency of the order of 20 kilocycles per second in the mixer 8. This may be accomplished in successive stages; for example, the signals may first be heterodyned to a frequency of 10 megacycles per second, then to 300 kilocycles per second and finally to 20 kilocycles per second by mixing with local oscillations of appropriate frequency. The 10 megacycles per

second stages may have a bandwidth of ± 200 kilocycles per second, the 300 kilocycles stages a bandwidth of ± 3 kilocycles per second and the final intermediate frequency circuit 9 is an oscillatory circuit tuned to 20 kilocycles per second and has a bandwidth of ± 200 cycles per second.

The effect of the successive heterodyning and bandwidth limitation process which has just been described is to integrate the successive reflected signals which are passed to the "pulsed" stages 4a of the receiver. If the aircraft giving the reflected signals has no component of velocity towards the transmitter and receiver, then the successive reflected signals will arrive in the same phase every $\frac{1}{500}$ sec., and will each set up oscillations in the final intermediate frequency circuits of the receiver. In view of the small pass band of these circuits and their correspondingly low decrement, the oscillation set up by each incoming signal will persist and will be reinforced by the next signal and so on, with the result that the amplitude of the oscillation set up will be directly proportional to the number of such signals received. The interference which is present in the train of signals with the reflected signals, however, is of a random character and the effect of the interference in successive time intervals during which the reflected signals are integrated will not be directly additive, so that the ratio of the amplitudes of the signal and the interference will be increased in relation to the minimum ratio of the amplitudes of said oscillatory signals and said interference in said train of signals during said time intervals.

Although there is theoretically no limit to the number of successive signals which may be integrated, and although in theory the pass band of the final intermediate frequency may be made as narrow as possible in the particular case which has been referred to above, this condition is not realised if the aeroplane has a component of velocity towards the transmitter and receiver, and the pass band must in this case be widened. The aircraft may be assumed to be flying slower than 150 metres/sec. so that the maximum rate of change of path length for the radio signals to and from the aircraft is 300 metres/sec. This means that the path length changes by half the transmitted wavelength, i.e., 1.5 metres, in $\frac{1}{200}$ sec. so that if the addition of the reflected signals is continued for more than this period, the relative phase of the radio frequency oscillator will have changed by more than 180° and the addition of further reflected signals will reduce the resultant signal amplitude. The decrement

of the integrating circuit must therefore be adjusted so that the oscillation set up by a single incoming reflected signal decays practically to zero in $1/200$ sec., that is, the bandwidth of the circuit must be of the order ± 100 or 200 cycles/sec. at 20 kilocycles/sec. Thus, 25 successive signals may be effectively added.

The operation of the system may alternatively be explained in the following manner. The signals sent out by the transmitter consist of a sequence of high frequency pulses and a signal of this type may be regarded as a continuous high frequency oscillation modulated by a recurrent modulating signal having a waveform consisting of a short pulse followed by a long interval. Such a waveform may be analysed into a series of components having frequencies equal to the frequency of repetition of the pulse and numerous harmonics of this frequency. The signal sent out by the transmitter therefore comprises a large number of component frequencies, namely, the carrier frequency and numerous sidebands spaced apart by said frequency of repetition. In the particular example quoted above the spectrum of the transmitted signal would consist of the carrier at 100 megacycles/sec., and a sequence of sidebands at $100 \pm .005 n$ megacycles/sec. where n may be 300 if the bandwidth of the transmitter is ± 1.5 megacycles/sec.

The receiving system which has been described above may alternatively be regarded as a system which only receives signals falling within such frequency bands. The effect of "pulsing" may be regarded as mixing or heterodyning the incoming signals by means of a pulse waveform comprising the frequency 5,000 cycles/sec. and numerous harmonics of the frequency which together make up the pulse waveform. If the "pulsed" stages are followed by a heterodyning stage which effectively limits the pass band to ± 200 cycles/sec., then it is clear that only input signals having frequencies lying within ± 200 cycles/sec. of the carrier frequency and a series of frequencies spaced from the carrier frequency by intervals of 5,000 cycles/sec. can give rise to an output in the heterodyning stage so that response of the receiver is effectively limited to those frequency bands containing some component of the signal to be received and in consequence the amplitude ratio between the signal and interference is improved due to the fact that components of interference having frequencies not contained in the desired signal are removed.

If the aircraft giving rise to the reflected signal is stationary, the

reflected signal will be of the same waveform and will have the same component frequencies, but if it is moving, the Doppler effect will modify these frequencies, and it can be shown that for aircraft speeds up to 150 metres/sec. and a carrier frequency of 100 megacycles/sec., the shift of frequency will not exceed 100 cycles/sec. The component of the reflected signals will therefore always lie well within one series of frequency bands ± 200 cycles/sec. wide centred at the frequencies $100 \pm .005 n$ megacycles/sec., and in the reception of such signals only these frequency bands are required.

The frequency bands required for the reception of the reflected signals may be still further narrowed by taking up the frequency shift due to the Doppler effect either manually or automatically. Thus, the frequency of the heterodyning oscillators may be varied by small variable condensers in their frequency determining circuits so as to maintain the frequency of the final I.F. signal at its assigned value and thus permit the bandwidth of the final I.F. circuits to be reduced considerably below ± 200 cycles/sec., thereby effecting a further reduction in the effect of interference. The necessary variation of frequency may be made manually by an observer or may be effected by the known methods of automatic frequency control.

Reflected signals from other reflecting objects moving relative to said reflecting object which it is desired to observe, for example, stationary objects will have a different frequency from the signals reflected by said reflecting object and may be rejected, by sufficiently reducing the pass band of the integrating device, or by arranging the integrating device to be non-responsive to the intermediate frequency signal derived from the reflected signals received from such objects.

In order to reduce the effect of oscillator drift, the local oscillations may be derived in known manner by mixing in the mixer 10 an oscillation derived from the carrier frequency oscillator 11 of the transmitter with an oscillation of the desired intermediate frequency derived from an oscillator 12, the frequency stability of which is good relative to the pass band required of the desired intermediate frequency. For example, the first heterodyning oscillation may be obtained by mixing the carrier frequency oscillations from the transmitter with a stable oscillation of 10 megacycles per second, the frequency drift of the latter oscillator being small with reference to 200 kilocycles per second. Alternatively, the carrier frequency of the transmitter may be syn-

thesised from a number of lower frequency oscillations including those required for the heterodyning stages of the receiver. Thus, if the I.F. frequencies of the receiver are to be 10 megacycles/sec., 300 kilocycles/sec. and 20 kilocycles/sec. respectively, and the frequency of the transmitted carrier and the reflected signal to be received is 100 megacycles/sec. the local oscillator frequencies required will be 90 megacycles/sec., 9.7 megacycles/sec. and 280 kilocycles/sec. respectively. These frequencies may be generated by starting with oscillations operating at frequencies of 20 and 280 kiloecycles/sec., mixing these oscillations to give 300 kilocycles/sec. oscillation; mixing this 300 kilocycles/sec. oscillation with a 9.7 megacycles/sec. oscillation to give a 10 megacycle oscillation and finally mixing this 10 megacycle oscillation with a 90 megacycle oscillation to give the 100 megacycle oscillation required for the transmitter. Any variation of frequency of these oscillators, excepting the 20 Kc. oscillations, will then not change the frequency of the final 20 kilocycle/sec. I.F. signal. This arrangement has the further advantage that, since the heterodyning oscillation is not derived from a signal frequency oscillation, the risk of a slight admixture of the signal frequency in the heterodyning frequency is prevented and interference, which the presence of such a component would cause, is therefore avoided.

The interfering effect of a steady carrier frequency in the methods of reception which have been described above may be reduced by modulating the carrier frequency of the transmitter at a very low frequency. It will be seen that the frequency of the transmitter must not change by more than a small fraction of 200 cycles/sec. in $\frac{1}{500}$ sec., as otherwise successive reflected signals will not add with a sufficient degree of accuracy because the received signal may be heterodyned by an oscillation derived from the transmitter $\frac{1}{500}$ sec. after it has itself transmitted. A frequency variation of 10 cycles/sec. may, however, be permitted in $\frac{1}{500}$ sec. and the frequency of the transmitter may be modulated over a range of ± 2500 cycles/sec., in a period of $\frac{1}{5}$ sec. That is to say, the frequency of the transmitter may be increased steadily during $\frac{1}{10}$ sec. and then decreased steadily during the following $\frac{1}{10}$ sec. and so on. This may be done by means of a mechanically rotated condenser in one of the frequency determining circuits of the transmitter. For a steady interfering signal, this frequency modulation of the transmitted

carrier will give freedom from interference from such a signal for 5000 - 400 $\times 100$ per cent.; i.e. 92 per cent. of each $\frac{1}{10}$ sec. period. A slower variation of frequency than that suggested above may of course be used.

If it is desired to examine a portion only of the envelope waveform of the oscillatory signals over a long succession of signals, the method described above may be used and the phase adjustment limited so that the receiver is only "pulsed" to receive the signal in the neighbourhood of that portion of the envelope waveform of the recurrent signal which is of interest. Further, the receiver may be pulsed when the signal is not present in order to integrate only the random interference, so as to enable the presence of the signal to be detected by the increase of the amplitudes of the integrated signal above that due to random interference alone.

Although the invention has been described as applied to the detection or determination of the position or distance of a reflecting object, it will be appreciated that it is generally applicable to the observation of recurrent oscillatory signals which are preferably recurrent at equal time intervals and which preferably have the same envelope waveform. The invention may be applied both prior to and subsequent to rectification. In the latter case, the integrating circuit may comprise a condenser.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:

1. The method of observing desired recurrent oscillatory signals in a train of signals including undesired random signals which comprises feeding the signals in said train during spaced time intervals each coinciding with the whole or a part of one of said desired signals to an integrating device, which is such that oscillations are set up therein by said desired signals; said signals being fed to said device in such manner that the oscillations set up in said device by said desired signals in successive time intervals add substantially in phase, whereby the minimum value of the ratio of the amplitude of said desired and undesired signals during said time intervals is increased.

2. The method according to Claim 1 in which said integrated signals are rectified and in which said rectified signals are fed to a further integrating device during spaced time intervals each coinciding with

the whole or a part of a rectified desired signal so as to increase the minimum ratio of the amplitude of the rectified desired and undesired signals during said 5 last mentioned time intervals.

3. The method according to Claim 1 or 2, in which, said oscillatory signals are changed to a different frequency and said oscillatory signals of different frequency 10 are fed to said integrating device.

4. The method of detecting or determining the position and/or distance of a reflecting object which comprise radiating short bursts of oscillatory signals and 15 receiving said oscillatory signals after reflection by said object by the method according to any of the preceding Claims.

5. The method according to Claims 3 20 and 4, and if desired, according to Claim 2, which comprises heterodyning said received oscillatory signals to a lower frequency by means of heterodyning oscillations so related in frequency 25 to the frequency of said radiated oscillations that changes in the frequency of said oscillatory signals of different frequency due to changes in the frequency of said radiated signals 30 and/or said heterodyning oscillations are reduced.

6. The method according to Claims 3 and 4 and, if desired according to Claim 5, in which the change of the frequency 35 of said received oscillatory signals is so controlled in accordance with variations in frequency thereof due to relative motion between said reflecting object and the receiver receiving said oscillatory 40 signals, that the changes in the frequency of said oscillations of different frequency due to said motion are reduced or eliminated.

7. The method according to Claim 5 or 45 6 in which the frequency of said radiated oscillatory signals is slowly varied over a predetermined frequency range, whereby the effect of interference of steady frequency upon the observation of said 50 signals is reduced.

8. Apparatus for carrying out the method of Claim 1 comprising an integrating device and switching means adapted to feed said signals or parts thereof to said 55 integrating device during said spaced time intervals, said integrating device being an oscillatory circuit of low decrement adapted to be set into oscillation by said desired oscillatory signals.

9. Apparatus according to Claim 8, in which said switching means comprises a thermionic valve which normally does not transmit signals but which is arranged to be rendered conducting so as to transmit

signals during said time intervals by 65 means of a voltage pulse applied to one of the electrodes thereof.

10. Apparatus according to Claim 8 or 9 for carrying out the method according to Claim 2, comprising a further integrating device and further switching means for feeding said rectified signals to said further integrating device during spaced time intervals.

11. Apparatus according to Claim 9 or 10 for carrying out the method of Claim 3, comprising means for heterodyning said desired oscillatory signals to a relatively low intermediate frequency and in which said integrating device is an oscillatory 80 circuit tuned to said intermediate frequency.

12. Apparatus according to Claim 11 for carrying out the method of Claim 6, in which means are provided for controlling 85 said intermediate frequency in accordance with variations in the frequency of said received oscillatory signals due to relative motion between said reflecting object and the receiver of said oscillatory signals.

13. Apparatus according to Claim 12 in which said integrating device is arranged to be substantially non-responsive to intermediate frequency signals resulting from the heterodyning of said oscillatory 95 signals received after reflection by other reflecting objects moving relative to said reflecting object.

14. Apparatus for carrying out the method of Claim 5, comprising a transmitter adapted to radiate oscillations at spaced time intervals and a receiver comprising apparatus according to Claim 11, 12 or 13 in which means are provided for deriving the heterodyning oscillations 100 for said receiver and also said radiated oscillations from a common oscillator or oscillators in such manner that changes in the frequency of the intermediate frequency signal in said receiver due to drift 110 of the frequency of said radiated and/or heterodyning oscillations is reduced.

15. Apparatus according to Claim 14, for carrying out the method of Claim 7, in which means are provided for slowly 115 varying the frequency of said radiated and said heterodyning oscillations within a predetermined frequency range.

16. The method of observing oscillatory signals, or for detecting or determining 120 the position or distance of a reflecting object substantially as described with reference to the accompanying drawing.

17. Apparatus for observing oscillatory signals, or for detecting or determining 125 the position or distance of a reflecting object, substantially as described with reference to the accompanying drawing.

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F. W. CACKETT,
Chartered Patent Agent.

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